

Tilburg University

E.O.Q.L.

van Batenburg, P.C.; Kriens, J.

Publication date:
1988

Document Version
Publisher's PDF, also known as Version of record

[Link to publication in Tilburg University Research Portal](#)

Citation for published version (APA):
van Batenburg, P. C., & Kriens, J. (1988). *E.O.Q.L. A revised and improved version of A.O.Q.L.* (Research Memorandum FEW). Faculteit der Economische Wetenschappen.

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

Take down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

CBM
R

7626
1988
348

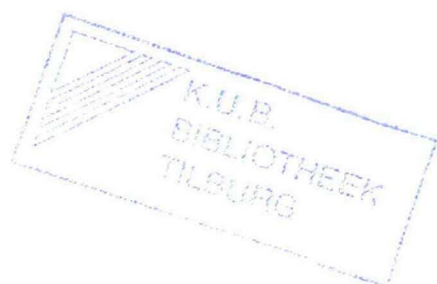
UNIVERSITY
...LIEKE
UNIVERSITEIT
BRABANT

POSTBOX 90153
5000 LE TILBURG
THE NETHERLANDS



DEPARTMENT OF ECONOMICS
RESEARCH MEMORANDUM

7626
88
348



E.O.Q.L. - A REVISED AND IMPROVED
VERSION OF A.O.Q.L.

Paul C. van Batenburg*)
J. Kriens**)

FEW 348

July 1988

*) Touche Ross Netherlands, Center for Quantitative
Methods and Statistics, World Trade Center, POB
72302, 1007 AV Amsterdam, The Netherlands.

**) Tilburg University, Department of Econometrics, POB
90153, 5000 LE Tilburg, The Netherlands.

E.O.Q.L. - a revised and improved version of A.O.Q.L.

1. Introduction

In the thirties H.F. Dodge and H.G. Romig developed the Average Outgoing Quality Limit sampling system, cf. H.F. Dodge and H.G. Romig (1959). It is a sampling system which guarantees that the average number of defectives after inspection does not exceed a limit chosen beforehand. A sample is taken from a population, all items in the sample are tested and if the number of defectives found in the sample exceeds a critical limit, all items in the population are tested. All defective items found in the sample or in full inspections are repaired/corrected or replaced by good items.

The method was one of the methods developed for use in the manufacture of communication apparatus and equipment for the Bell Telephone System. The method was translated for application in an auditing environment by J. Kriens (cf. J. Kriens and A.C. Dekkers (1979)) and later on for application in the control of administrative processes by J. Kriens and R.H. Veenstra (1985). The method has already been successfully applied for many years by the Dutch accounting firm Touche Ross Netherlands and by a number of its clients.

Unfortunately the statistical derivation presented by Dodge and Romig is not completely correct. In this article we present a correct derivation. Because we treat the quality after the inspection more explicitly as a stochastic variable than Dodge and Romig do, we call the improved version Expected Outgoing Quality Limit instead of Average Outgoing Quality Limit.

Section 2 contains the model by Dodge and Romig, section 3 shows the error in it and section 4 contains the revised version of the model. Finally section 5 discusses the numerical solution of the E.O.Q.L.-model.

2. Dodge and Romig's A.O.Q.L.-method

In a population with N elements, there are $M = pN$ errors. The number of errors $\underline{k}^*)$ in the sample has a hypergeometric distribution, which for small values of p and $n \ll N$ can be approximated by a Poisson distribution with parameter np .

If the number of errors in the sample is smaller than or equal to the acceptance number k_0 , only these errors are corrected, in the other case all elements of the population will be inspected and corrected if necessary. The expected value of the number of elements of the population to be inspected is equal to

$$(2.1) \quad I = nP[\underline{k} \leq k_0] + NP[\underline{k} > k_0].$$

Dodge and Romig state that the fraction of errors after the inspection is given by

$$(2.2) \quad p_A = \frac{M - pI}{N} = p \frac{N - n}{N} P[\underline{k} \leq k_0]$$

(o.c. p. 37). The relation between p_A and p can for given values of N , n and k_0 be represented as in fig. 2.1. For small values of p the curve is somewhat below the bisector; there is a maximum for $p = p_1$ and then the curve approximates 0 for p tending to 1.

*) In this paper random variables will be underlined.

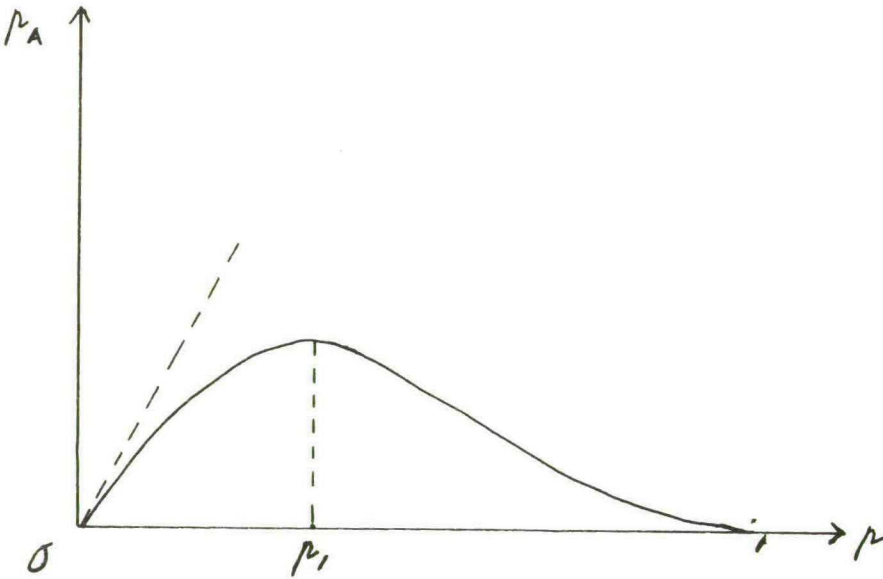


Figure 2.1. The relationship between p_A and p for given values of N , n and k_0 (in this figure different scales are used for each axis; as a consequence the tangent to the curve lies in $p = 0$ above the bisector).

The value of p_1 can be found by putting the derivative of p_A to p equal to zero and solving for p . Now

$$(2.3) \quad \frac{dp_A}{dp} = \frac{N-n}{N} \left[P[\underline{k} \leq k_0] + p \frac{dP[\underline{k} \leq k_0]}{dp} \right].$$

From

$$(2.4) \quad P[\underline{k} \leq k_0] = \sum_{k=0}^{k_0} e^{-np} \frac{(np)^k}{k!}$$

it follows

$$(2.5) \quad \frac{dP[\underline{k} \leq k_0]}{dp} = \sum_{k=0}^{k_0} \frac{e^{-np} (np)^k}{k!} \left(-n + \frac{k}{p} \right) =$$

$$-nP[\underline{k} \leq k_0] + \frac{1}{p} \sum_{k=0}^{k_0} kP[\underline{k} = k].$$

Using the following property of the Poisson distribution

$$(2.6) \quad kP[\underline{k} = k] = npP[\underline{k} = k-1]$$

(2.5) can be rewritten as

$$(2.7) \quad \frac{dP[\underline{k} \leq k_0]}{dp} = -nP[\underline{k} = k_0]$$

and thus

$$(2.8) \quad \frac{dp_A}{dp} = \frac{N-n}{N} [P[\underline{k} \leq k_0] - npP[\underline{k} = k_0]].$$

Putting the right hand side of (2.8) equal to zero, we find that p_1 satisfies

$$(2.9) \quad P[\underline{k} \leq k_0 | np_1] - np_1 P[\underline{k} = k_0 | np_1] = 0,$$

or, with $x = np_1$

$$(2.10) \quad P[\underline{k} \leq k_0 | x] - xP[\underline{k} = k_0 | x] = 0.$$

From this equation x can be found with Newton's method. That we really get a maximum follows from figure 2.1. or may be checked by computing the second derivative. The value of the maximum equals

$$(2.11) \quad p_L = p_1 \frac{N-n}{N} P[\underline{k} \leq k_0 | x] = \left(\frac{1}{n} - \frac{1}{N}\right)x^2 P[\underline{k} = k_0 | x].$$

Dodge and Romig introduce the variable

$$y = x \sum_{k=0}^{k_0} e^{-x} \frac{x^k}{k!},$$

which with (2.9) can be rewritten as

$$y = x^2 P[\underline{k} = k_0 | x].$$

Then (2.11) runs

$$(2.12) \quad p_L = \left(\frac{1}{n} - \frac{1}{N}\right)y.$$

For given values of k_0 , N and n , the maximum value p_L can be computed. In practice, however, the value of p_L is chosen and n then follows from

$$(2.13) \quad n = \frac{Ny}{Np_L + y}.$$

For a given value of N and a chosen level p_L , n is still a function of k_0 , so there are a number of combinations (n, k_0) which satisfy the condition set to p_A . Dodge and Romig try to find that combination (n, k_0) which minimizes I , using an estimate of the quality p before inspection. Their method does not lead to the global optimum in all cases, cf. A. Hald (1981) and R.H. Veenstra and J.C. Buysse (1985).

3. The error in the Dodge and Romig-model

Formula (2.2) is not completely correct, which can be shown as follows. The expected value of the number of corrections \underline{R} is

$$(3.1) \quad \mathbb{E} \underline{R} = \sum_{k=0}^{k_0} kP[\underline{k} = k] + MP[\underline{k} > k_0].$$

In stead of this value Dodge and Romig use for the expected number of corrections

$$(3.2) \quad pI = npP[\underline{k} \leq k_0] + MP[\underline{k} > k_0]$$

(cf. formula (2.1)), implying

$$(3.3) \quad \sum_{k=0}^{k_0} kP[\underline{k} = k] = npP[\underline{k} \leq k_0].$$

This formula is not correct: after division of both sides by $P[\underline{k} \leq k_0]$, the left hand side equals the expected value of the number of errors under the condition that the population is not rejected, whereas the right hand side equals the unconditional expected value of \underline{k} .

The difference between both terms is

$$(3.4) \quad npP[\underline{k} \leq k_0] - \sum_{k=0}^{k_0} kP[\underline{k} = k] = npP[\underline{k} \leq k_0] - \sum_{k=0}^{k_0} npP[\underline{k} = k-1]$$

$$= npP[\underline{k} \leq k_0] - npP[\underline{k} \leq k_0-1] = npP[\underline{k} = k_0].$$

This difference is not large, but putting it equal to zero has as a consequence $\frac{dp_A}{dp} > 0$ for every p ! (cf. (2.3) and (2.5)).

4. The improved version of the A.O.Q.L.-method: the E.O.Q.L.-method

We consider the fraction defectives after inspection as a random variable p_A with distribution

$$(4.1) \quad p_A = p - \frac{k}{N} \quad (k = 0, 1, \dots, k_0 \text{ } (\leq n)) \text{ with probability } P[\underline{k} = k]$$

$$p_A = 0 \quad \text{with probability } P[\underline{k} > k_0]$$

\underline{k} being again Poisson distributed, cf. (2.4). The expected value of p_A equals

$$(4.2) \quad \mathcal{E} p_A = \sum_{k=0}^{k_0} (p - \frac{k}{N}) P[\underline{k} = k].$$

With (2.6), (4.2) can be rewritten as

$$(4.3) \quad \mathcal{E} p_A = p \frac{N-n}{N} P[\underline{k} \leq k_0] + \frac{np}{N} P[\underline{k} = k_0].$$

In most cases the maximum value of $\mathcal{E} p_A$ can be found by putting the derivative to p equal to zero and next solving for p , cf. however section 5. This derivative is

$$(4.4) \quad \frac{d \mathcal{E} p_A}{dp} = \frac{N-n}{N} \left[P[\underline{k} \leq k_0] + p \frac{dP[\underline{k} \leq k_0]}{dp} \right] + \frac{n}{N} \left[P[\underline{k} = k_0] + p \frac{dP[\underline{k} = k_0]}{dp} \right] = \frac{N-n}{N} P[\underline{k} \leq k_0] - P[\underline{k} = k_0] \cdot [np - \frac{n}{N} (1+k_0)],$$

using

$$\frac{dP[\underline{k} \leq k_0]}{dp} = -nP[\underline{k} = k_0]$$

and

$$\frac{dP[\underline{k} = k_0]}{dp} = P[\underline{k} = k_0](-n + \frac{k_0}{p}).$$

Applying the same procedure as in section 2 we find for the required sample size

$$(4.5) \quad n = \frac{Ny}{Np_L + \frac{k_0}{x} y}.$$

However, solving $x = np_1$, for which (4.4) reaches the value 0 has become more complicated than in section 2 as is shown by example 4.2. Example 4.1 is more as an introduction.

Example 4.1

Suppose $k_0 = 0$, then according to Dodge and Romig $x = 1$, cf. (2.9) and $y = x^2 P[\underline{k} = 0] = e^{-1}$, so (2.13) leads to

$$n = \frac{e^{-1}}{p_L + e^{-1}/N}.$$

In our case (4.4) also leads to $x = 1$, $y = e^{-1}$ and the required sample size is

$$n = \frac{e^{-1}}{p_L},$$

a size independent of N .

Interesting to notice is that the maximum value of $\mathcal{E}(p_A)$ will be reached in $p_1 = \frac{1}{n} = ep_L$. When using hypergeometric probabilities, $\mathcal{E}(p_A)$ can not be maximized by differentiation: a numerical solution can then be found, however, by iterative searching in the neighbourhood of $p_1 = ep_L$.

Example 4.2

Assume now $k_0 = 1$. According to Dodge and Romig x is a solution of $x^2 - x - 1 = 0$, cf. (2.10), and n follows from (2.13) with $x = \frac{1}{2}(1 + \sqrt{5})$. According to the E.O.Q.L.-method x is a solution of, cf. (4.4),

$$(4.6) \quad \frac{N-n}{N} P[\underline{k} \leq 1] - P[\underline{k} = 1](x - 2 \frac{n}{N}) = 0.$$

or, after substitution of the Poisson distribution

$$(4.7) \quad x^2 - (1 + \frac{n}{N})x - (1 - \frac{n}{N}) = 0.$$

There is an analogy with the Dodge-Romig solution, but apart from that, we now have an identification problem: to compute x we must know the quotient $\frac{n}{N}$, whereas to find n we must know x .

As $\frac{n}{N}$ varies between 0 and 1, x can vary from $\frac{1 + \sqrt{5}}{2}$ (the solution of $x^2 - x - 1 = 0$) as $\frac{n}{N} \downarrow 0$, to 2 (the solution of $x^2 - 2x = 0$) as $\frac{n}{N} \uparrow 1$. The values of x as given by Dodge and Romig are, as can be shown by putting $\frac{n}{N} \downarrow 0$ in (4.4), lower bounds for all possible solutions. A.J. Simons (1988) has shown in a general formulation that $k_0 + 1$ is an upperbound for x .

Besides the identification problem, the E.O.Q.L.-solution in example 4.1 is not completely satisfactory either, because for $p_L = 1$, we still find

$n > 0$. A rigorous numerical solution of the E.O.Q.L.-model is given in the next section.

5. A general numerical solution for the E.O.Q.L.-model

For given values of N and k_0 we define the function $E(n, p)$ as follows:

$$(5.1) \quad E: [0, N] \times [0, 1] \rightarrow \mathcal{R}, \quad E(n, p) = \sum_{k=0}^{k_0} \left(p - \frac{k}{N}\right) P[\underline{k} = k],$$

which function is identical to (4.2). The problem then is to find the minimum value n^* of n such that $E \leq p_L$ for every p . Put in another way: if we define

$$(5.2) \quad E^* = E - p_L,$$

we are looking for the minimum value of n , such that $E^* \leq 0$ for every p . This can be done by writing n as a function of p .

Figure 5.1. may serve as an illustration; the shaded area is the feasible region.

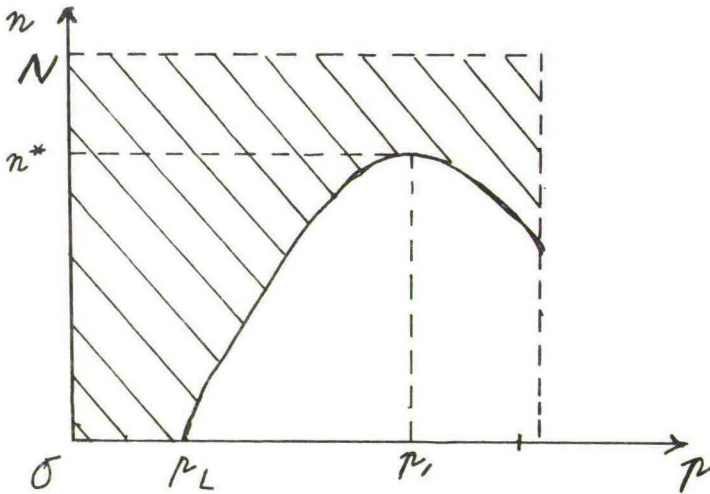


Figure 5.1. The indifference curve $E^* = 0$.

Example 5.1

Assume again $k_0 = 0$. Then

$$(5.3) \quad E^* = 0 \Rightarrow pe^{-np} - p_L = 0$$

and

$$(5.4) \quad n(p) = -\frac{1}{p} \log \frac{p_L}{p}.$$

By differentiating we find that $n(p)$ has its maximum value for

$$(5.5) \quad p_1 = ep_L$$

and

$$(5.6) \quad n^* = \frac{e^{-1}}{p_L}.$$

Note that again $n^*p_1 = 1$. This derivation may not be applicable if the maximum is reached on the boundary of the feasible region e.g. if $p_L = 1$ or if $p_L < \frac{e^{-1}}{N}$; in the first case $n^* = 0$ and in the second $n^* = N$.

The solution which minimizes n subject to $E^* \leq 0$ for all p satisfies the original conditions $\frac{d \mathcal{E} p_A}{dp} = 0$ and (4.5).

Contrary to the Dodge and Romig-method n and p are now treated as two different variables and not only in the combination $x = np$. As a consequence the identification problem mentioned at the end of section 4 no longer exists.

In order to describe the algorithm we rewrite the original conditions. The first one is rewritten as

$$(5.7) \quad \frac{N-n}{N} \sum_{k=0}^{k_0} \frac{(np)^k}{k!} - \frac{(np)^{k_0}}{k!} \left[np - \frac{n}{N} (1 + k_0) \right] = 0,$$

or, for given values of N and k_0 as

$$(5.8) \quad g(n, p) = 0.$$

With $P_R = P[\underline{k} = k_0]$ equation (4.5) can be rewritten in the original variables as

$$(5.9) \quad n^* = \frac{p_L}{P_R p_1 (p_1 - \frac{k_0}{N})},$$

or, for given values of N , p_L and k_0 , as

$$(5.10) \quad n^* = f(n, p_1).$$

The algorithm first computes a combination (n, p) which satisfies (5.8) and next checks whether (5.10) is also satisfied. If not, it makes a new iteration. The algorithm exploits the property that, if for a given value of p_L , there exist combinations $X = (n_x, p_x)$ and $Y = (n_y, p_y)$ such that $g(X) = 0$, $g(Y) = 0$ and $[n_x - f(X)][n_y - f(Y)] < 0$, the function f has just one solution $n = n^* = f(x, p)$ which satisfies $g(n, p) = 0$.

The steps in each iteration are as follows.

- (1) Check whether for the chosen value of p_L combinations $X = (n_x, p_x)$ and $Y = (n_y, p_y)$ can be found such that $[n_x - f(X)][n_y - f(Y)] < 0$; natural choices for X and Y are $X = (n(\frac{k_0}{N}), \frac{k_0}{N})$ and $Y = (n(1), 1)$.

If such points can be found, go to (2); if this is not the case the optimum can be found by studying the boundary points of $E^* = 0$ (cf. example 5.1).

- (2) Compute a new value $p_1 = \frac{1}{2} (p_x + p_y)$.
- (3) Find the value $n(p_1)$ satisfying (5.8).
- (4) Compute $f(n(p_1), p_1)$.
- (5) Determine $t = f(n(p_1), p_1) - n(p_1)$.
- (6) If $t = 0$, the optimum is found;
if $t > 0$, choose $X = (n(p_1), p_1)$;
if $t < 0$, choose $Y = (n(p_1), p_1)$.
- (7) Go back to step (2).

It can be proved that this algorithm converges for any set N , p_L , k_0 to the optimal combination $(n^*(k_0), p_1(k_0))$, cf. A.J. Simons (1988).

So for every chosen value of k_0 we can compute the optimal corresponding value $n^*(k_0)$ of n^* . The freedom in choice of a combination $(k_0, n^*(k_0))$ can, just as in the Dodge Romig-model be used to minimize the expected total number of items $\mathcal{E}(\underline{I}(k_0))$ to be inspected. Thus

$$(5.11) \quad \min_{k_0} \mathcal{E}(\underline{I}(k_0)) = n^*(k_0)P[\underline{k} \leq k_0] + NP[\underline{k} > k_0]$$

results in the minimum expected number of inspections as a function of p . Also in the case of the E.O.Q.L.-method the available freedom in choosing an adequate value of k_0 can only be used if there is some knowledge about the value of p before inspection, which does not conflict with (5.4): only values of $p > p_L$ give sample sizes $n > 0$.

References

- Dodge, H.F. and H.G. Romig (1959), Sampling Inspection Tables, 2nd Ed., New York, John Wiley and Sons.
- Hald, A. (1981), Statistical Theory of Sampling by Attributes, New York, Academic Press.
- Kriens, J. and A.C. Dekkers (1979), Statistical Sampling in Auditing, Leiden, Stenfert Kroese (in Dutch).
- Kriens, J. and R.H. Veenstra (1985), Statistical Sampling in Internal Control by using the A.O.Q.L.-system, The Statistician 34, 383-390.
- Simons, A.J. (1988), Statistical Quality Control using the E.O.Q.L.-method: a revised and improved version, Department of Econometrics, Tilburg University (in Dutch).
- Veenstra, R.H. and J.C. Buysse (1985), Optimizing Applications of Statistical Sampling in the Administration, De Accountant 91, 561-563 (in Dutch).

IN 1987 REEDS VERSCHENEN

- 242 Gerard van den Berg
Nonstationarity in job search theory
- 243 Annie Cuyt, Brigitte Verdonk
Block-tridiagonal linear systems and branched continued fractions
- 244 J.C. de Vos, W. Vervaat
Local Times of Bernoulli Walk
- 245 Arie Kapteyn, Peter Kooreman, Rob Willemse
Some methodological issues in the implementation
of subjective poverty definitions
- 246 J.P.C. Kleijnen, J. Kriens, M.C.H.M. Lafleur, J.H.F. Pardoel
Sampling for Quality Inspection and Correction: AOQL Performance
Criteria
- 247 D.B.J. Schouten
Algemene theorie van de internationale conjuncturele en structurele
afhankelijkheden
- 248 F.C. Bussemaker, W.H. Haemers, J.J. Seidel, E. Spence
On (v,k,λ) graphs and designs with trivial automorphism group
- 249 Peter M. Kort
The Influence of a Stochastic Environment on the Firm's Optimal Dyna-
mic Investment Policy
- 250 R.H.J.M. Gradus
Preliminary version
The reaction of the firm on governmental policy: a game-theoretical
approach
- 251 J.G. de Gooijer, R.M.J. Heuts
Higher order moments of bilinear time series processes with symmetri-
cally distributed errors
- 252 P.H. Stevers, P.A.M. Versteijne
Evaluatie van marketing-activiteiten
- 253 H.P.A. Mulders, A.J. van Reeken
DATAAL - een hulpmiddel voor onderhoud van gegevensverzamelingen
- 254 P. Kooreman, A. Kapteyn
On the identifiability of household production functions with joint
products: A comment
- 255 B. van Riel
Was er een profit-squeeze in de Nederlandse industrie?
- 256 R.P. Gilles
Economies with coalitional structures and core-like equilibrium con-
cepts

- 257 P.H.M. Ruys, G. van der Laan
Computation of an industrial equilibrium
- 258 W.H. Haemers, A.E. Brouwer
Association schemes
- 259 G.J.M. van den Boom
Some modifications and applications of Rubinstein's perfect equilibrium model of bargaining
- 260 A.W.A. Boot, A.V. Thakor, G.F. Udell
Competition, Risk Neutrality and Loan Commitments
- 261 A.W.A. Boot, A.V. Thakor, G.F. Udell
Collateral and Borrower Risk
- 262 A. Kapteyn, I. Woittiez
Preference Interdependence and Habit Formation in Family Labor Supply
- 263 B. Bettonvil
A formal description of discrete event dynamic systems including perturbation analysis
- 264 Sylvester C.W. Eijffinger
A monthly model for the monetary policy in the Netherlands
- 265 F. van der Ploeg, A.J. de Zeeuw
Conflict over arms accumulation in market and command economies
- 266 F. van der Ploeg, A.J. de Zeeuw
Perfect equilibrium in a model of competitive arms accumulation
- 267 Aart de Zeeuw
Inflation and reputation: comment
- 268 A.J. de Zeeuw, F. van der Ploeg
Difference games and policy evaluation: a conceptual framework
- 269 Frederick van der Ploeg
Rationing in open economy and dynamic macroeconomics: a survey
- 270 G. van der Laan and A.J.J. Talman
Computing economic equilibria by variable dimension algorithms: state of the art
- 271 C.A.J.M. Dirven and A.J.J. Talman
A simplicial algorithm for finding equilibria in economies with linear production technologies
- 272 Th.E. Nijman and F.C. Palm
Consistent estimation of regression models with incompletely observed exogenous variables
- 273 Th.E. Nijman and F.C. Palm
Predictive accuracy gain from disaggregate sampling in arima - models

- 274 Raymond H.J.M. Gradus
The net present value of governmental policy: a possible way to find the Stackelberg solutions
- 275 Jack P.C. Kleijnen
A DSS for production planning: a case study including simulation and optimization
- 276 A.M.H. Gerards
A short proof of Tutte's characterization of totally unimodular matrices
- 277 Th. van de Klundert and F. van der Ploeg
Wage rigidity and capital mobility in an optimizing model of a small open economy
- 278 Peter M. Kort
The net present value in dynamic models of the firm
- 279 Th. van de Klundert
A Macroeconomic Two-Country Model with Price-Discriminating Monopolists
- 280 Arnoud Boot and Anjan V. Thakor
Dynamic equilibrium in a competitive credit market: intertemporal contracting as insurance against rationing
- 281 Arnoud Boot and Anjan V. Thakor
Appendix: "Dynamic equilibrium in a competitive credit market: intertemporal contracting as insurance against rationing"
- 282 Arnoud Boot, Anjan V. Thakor and Gregory F. Udell
Credible commitments, contract enforcement problems and banks: intermediation as credibility assurance
- 283 Eduard Ponds
Wage bargaining and business cycles a Goodwin-Nash model
- 284 Prof.Dr. hab. Stefan Mynarski
The mechanism of restoring equilibrium and stability in polish market
- 285 P. Meulendijks
An exercise in welfare economics (II)
- 286 S. Jørgensen, P.M. Kort, G.J.C.Th. van Schijndel
Optimal investment, financing and dividends: a Stackelberg differential game
- 287 E. Nijssen, W. Reijnders
Privatisering en commercialisering; een oriëntatie ten aanzien van verzelfstandiging
- 288 C.B. Mulder
Inefficiency of automatically linking unemployment benefits to private sector wage rates

- 289 M.H.C. Paardekooper
A Quadratically convergent parallel Jacobi process for almost diagonal matrices with distinct eigenvalues
- 290 Pieter H.M. Ruys
Industries with private and public enterprises
- 291 J.J.A. Moors & J.C. van Houwelingen
Estimation of linear models with inequality restrictions
- 292 Arthur van Soest, Peter Kooreman
Vakantiebestemming en -bestedingen
- 293 Rob Alessie, Raymond Gradus, Bertrand Melenberg
The problem of not observing small expenditures in a consumer expenditure survey
- 294 F. Boekema, L. Oerlemans, A.J. Hendriks
Kansrijkheid en economische potentie: Top-down en bottom-up analyses
- 295 Rob Alessie, Bertrand Melenberg, Guglielmo Weber
Consumption, Leisure and Earnings-Related Liquidity Constraints: A Note
- 296 Arthur van Soest, Peter Kooreman
Estimation of the indirect translog demand system with binding non-negativity constraints

IN 1988 REEDS VERSCHENEN

- 297 Bert Bettonvil
Factor screening by sequential bifurcation
- 298 Robert P. Gilles
On perfect competition in an economy with a coalitional structure
- 299 Willem Selen, Ruud M. Heuts
Capacitated Lot-Size Production Planning in Process Industry
- 300 J. Kriens, J.Th. van Lieshout
Notes on the Markowitz portfolio selection method
- 301 Bert Bettonvil, Jack P.C. Kleijnen
Measurement scales and resolution IV designs: a note
- 302 Theo Nijman, Marno Verbeek
Estimation of time dependent parameters in linear models
using cross sections, panels or both
- 303 Raymond H.J.M. Gradus
A differential game between government and firms: a non-cooperative
approach
- 304 Leo W.G. Strijbosch, Ronald J.M.M. Does
Comparison of bias-reducing methods for estimating the parameter in
dilution series
- 305 Drs. W.J. Reijnders, Drs. W.F. Verstappen
Strategische bespiegelingen betreffende het Nederlandse kwaliteits-
concept
- 306 J.P.C. Kleijnen, J. Kriens, H. Timmermans and H. Van den Wildenberg
Regression sampling in statistical auditing
- 307 Isolde Woittiez, Arie Kapteyn
A Model of Job Choice, Labour Supply and Wages
- 308 Jack P.C. Kleijnen
Simulation and optimization in production planning: A case study
- 309 Robert P. Gilles and Pieter H.M. Ruys
Relational constraints in coalition formation
- 310 Drs. H. Leo Theuns
Determinanten van de vraag naar vakantiereizen: een verkenning van
materiële en immateriële factoren
- 311 Peter M. Kort
Dynamic Firm Behaviour within an Uncertain Environment
- 312 J.P.C. Blanc
A numerical approach to cyclic-service queueing models

- 313 Drs. N.J. de Beer, Drs. A.M. van Nunen, Drs. M.O. Nijkamp
Does Morkmon Matter?
- 314 Th. van de Klundert
Wage differentials and employment in a two-sector model with a dual labour market
- 315 Aart de Zeeuw, Fons Groot, Cees Withagen
On Credible Optimal Tax Rate Policies
- 316 Christian B. Mulder
Wage moderating effects of corporatism
Decentralized versus centralized wage setting in a union, firm, government context
- 317 Jörg Glombowski, Michael Krüger
A short-period Goodwin growth cycle
- 318 Theo Nijman, Marno Verbeek, Arthur van Soest
The optimal design of rotating panels in a simple analysis of variance model
- 319 Drs. S.V. Hannema, Drs. P.A.M. Versteijne
De toepassing en toekomst van public private partnership's bij de grote en middelgrote Nederlandse gemeenten
- 320 Th. van de Klundert
Wage Rigidity, Capital Accumulation and Unemployment in a Small Open Economy
- 321 M.H.C. Paardekooper
An upper and a lower bound for the distance of a manifold to a nearby point
- 322 Th. ten Raa, F. van der Ploeg
A statistical approach to the problem of negatives in input-output analysis
- 323 P. Kooreman
Household Labor Force Participation as a Cooperative Game; an Empirical Model
- 324 A.B.T.M. van Schaik
Persistent Unemployment and Long Run Growth
- 325 Dr. F.W.M. Boekema, Drs. L.A.G. Oerlemans
De lokale produktiestructuur doorgelicht.
Bedrijfstakverkenningen ten behoeve van regionaal-economisch onderzoek
- 326 J.P.C. Kleijnen, J. Kriens, M.C.H.M. Lafleur, J.H.F. Pardoel
Sampling for quality inspection and correction: AOQL performance criteria

- 327 Theo E. Nijman, Mark F.J. Steel
Exclusion restrictions in instrumental variables equations
- 328 B.B. van der Genugten
Estimation in linear regression under the presence of heteroskedasticity of a completely unknown form
- 329 Raymond H.J.M. Gradus
The employment policy of government: to create jobs or to let them create?
- 330 Hans Kremers, Dolf Talman
Solving the nonlinear complementarity problem with lower and upper bounds
- 331 Antoon van den Elzen
Interpretation and generalization of the Lemke-Howson algorithm
- 332 Jack P.C. Kleijnen
Analyzing simulation experiments with common random numbers, part II: Rao's approach
- 333 Jacek Osiewalski
Posterior and Predictive Densities for Nonlinear Regression. A Partly Linear Model Case
- 334 A.H. van den Elzen, A.J.J. Talman
A procedure for finding Nash equilibria in bi-matrix games
- 335 Arthur van Soest
Minimum wage rates and unemployment in The Netherlands
- 336 Arthur van Soest, Peter Kooreman, Arie Kapteyn
Coherent specification of demand systems with corner solutions and endogenous regimes
- 337 Dr. F.W.M. Boekema, Drs. L.A.G. Oerlemans
De lokale produktiestructuur doorgelicht II. Bedrijfstakverkenningen ten behoeve van regionaal-economisch onderzoek. De zeescheepsnieuw-bouwindustrie
- 338 Gerard J. van den Berg
Search behaviour, transitions to nonparticipation and the duration of unemployment
- 339 W.J.H. Groenendaal and J.W.A. Vingerhoets
The new cocoa-agreement analysed
- 340 Drs. F.G. van den Heuvel, Drs. M.P.H. de Vor
Kwantificering van ombuigen en bezuinigen op collectieve uitgaven 1977-1990
- 341 Pieter J.F.G. Meulendijks
An exercise in welfare economics (III)

- 342 W.J. Selen and R.M. Heuts
A modified priority index for Günther's lot-sizing heuristic under capacitated single stage production
- 343 Linda J. Mittermaier, Willem J. Selen, Jeri B. Waggoner, Wallace R. Wood
Accounting estimates as cost inputs to logistics models
- 344 Remy L. de Jong, Rashid I. Al Layla, Willem J. Selen
Alternative water management scenarios for Saudi Arabia
- 345 W.J. Selen and R.M. Heuts
Capacitated Single Stage Production Planning with Storage Constraints and Sequence-Dependent Setup Times
- 346 Peter Kort
The Flexible Accelerator Mechanism in a Financial Adjustment Cost Model
- 347 W.J. Reijnders en W.F. Verstappen
De toenemende importantie van het verticale marketing systeem

Bibliotheek K. U. Brabant



17 000 01065971 3